# Why Does It Cost How Much?

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## Abstract

There is great concern for the competitiveness of the aerospace industry today. This paper examines the concept of competitiveness by relating the levels of the genopersistation recursion to cost.

## Introduction

The cost estimating community focuses on how much systems cost. Some cost estimates are based on cost estimating relationships derived from data. Other cost estimates are based detailed a buildup of costs based upon perceived purchases, analogy, expert opinion, or just plain guesses. All cost estimates are just estimates. Most cost estimates have little or no relationship to the system which is finally delivered. Many cost estimates have little or no relationship to the final cost. Why? The cost estimating community rarely asks the question "Why will the system cost how much?"

The cost estimating community rarely focuses on why a system will cost what it will. It is a well known fact that the system perceived at the time of early cost estimates is usually quite different from the system delivered. Thus a good cost estimate must include a good forecast of what the system will be upon delivery. The few really good cost estimators know this and have developed technology which lets them predict key characteristics of the evolved system. Examples include normal weight and complexity growth. Other informed estimators will use risk analysis to balance off "things which go right" with "things which go wrong." Unfortunately these informed estimators are rarely permitted to use these "private" estimates because "the system would cost too much to sell" or "the parameters you have used do not represent our system" or "we are going to do it differently this time." The result is "cost overruns."

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The Freiman curve [11] in Figure 1 links cost growth to the ratio of actual to bid in the shape of a bathtub with underestimates creating significant cost growth above what actual should have been. This curve, along with collected data indicate that lowest bid is strongly correlated to highest cost. The culture of the government low bid is an excellent example of why systems cost more that they should.

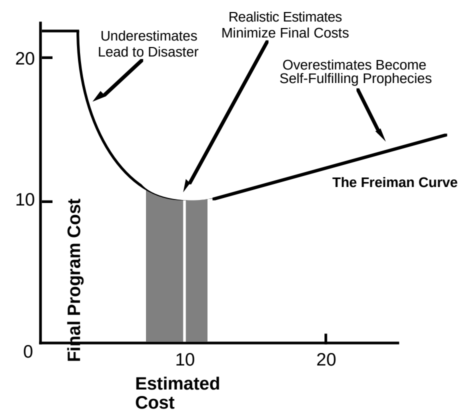


Figure 1: The Freiman Curve

Oops! Haven't we just focused on why the system cost how much? Did this argument have anything to do with the system? Very little really. It had to do with the system to genopersistate the system [4]. To understand why the system cost how much we must understand the concept of genopersistation, a compound word based upon the root words "genesis" and "persistence" which when compounded imply a process of bringing into being and then hanging on until final annihilation. To genopersistate a system is to apply the functions conceptual design, design, develop, test and evaluate, produce, deploy, operate, support, evolve, retire, and manage to the system.

The genopersistation recursion includes the system, the system to genopersistate the system, the system to genopersistate the system to genopersistate the system, and the system to genopersistate the system to genopersistate the system to genopersistate the system.

Representative functions at the respective levels of the recursion include navigate-aircraft, produce (navigate aircraft), design ( produce ( navigate-aircraft )), and evolve ( design ( produce ( navigate aircraft ))). That is, each function on each level of the recursion operates on all of the functions of the system one level lower in the recursion.

Careful analysis leads to the conclusion that the system costs nothing. Virtually all of the cost is generated within the system to genopersistate ( the system ) - the project. Most of the cost is determined in the system to genopersistate ( the system to genopersistate ( the system )) - the "management" of the project. Most cost reduction is determined in the system to genopersistate ( the system to genopersistate ( the system to genopersistate ( the system ))) - an unnamed, virtually unperceived, and rarely implemented system which contains my research area of genopersistation-for-competitiveness which addresses the functions genopersistate ( genopersistate (genopersistate ( system ))), genopersistate (genopersistate ( system )), and genopersistate (system).

To understand why a system costs how much, all four levels of the recursion must be examined.

## Cost and the System

Although the system costs nothing, cost is allocated to the system. In theory, Military Standard 881 [1] allocates cost to end items. The result is really a hodgepodge of subsystems and functions. Activity based costing [19] allocates cost to system functions. This fact that cost is allocated to the system provides the incorrect assumption that a system costs something. That is thus a fiction of the financial world. Or is it?

The functions of the system do, however, drive cost [8] through the requirements [12] and specifications which are implemented by the functions of the project or project activities. See Figure 2.

Since the requirements and specifications may be viewed as constraints [8]

$$g(x) = \text{constant},$$

consider the minimization problem

| | |
|---|---|
| Minimize | $f(x)$ |
| Subject to | $g(x) = \text{constant}$ |

with genopersistation cost as the objective f(x) and the requirements and specifications as constraints.

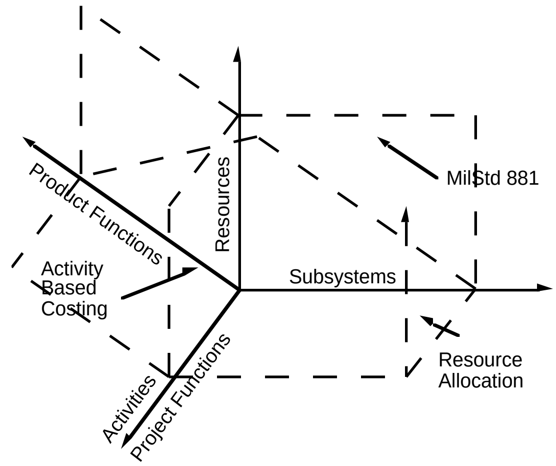


Figure 2: Resource Allocation To The System

There are two cases. If a constraint is not active then the minimal cost is not modified by that constraint. However, a cost is incurred to manage the constraint. If a constraint is active then the constrained minimal cost is higher than the previously unconstrained cost and a cost is incurred to manage the constraint. The conclusion is that any constraint increases cost. Hence all requirements and specifications increase cost. This seems to imply that minimal cost is attained by eliminating all constraints. This is unrealistic since it is the constraints that provide the structure [2] of the design. The goal is thus to attain the minimal core of requirements and specifications which will provide the desired system. This provides the lowest realistic cost.

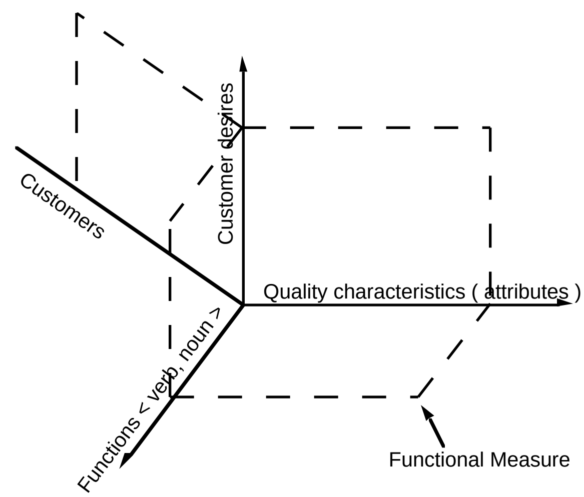


Figure 3: Requirements as Functional Measures

The design-for-cost process [7] permits parameters other than cost to be used in the objective function as long as cost is one of the parameters. Quality characteristics such as failure rate and availability are examples of other permissible parameters. Quality function deployment [6] is an excellent method for obtaining appropriate quality characteristics. This can be seen in Figure 3 which represents the derivation of requirements from customers and their desires. The minimization of multiple objectives can be achieved through multiobjective optimization [10].

## Cost and the System to Genopersistate the System

There are an infinite number of ways to genopersistate a given system. Each of these, represented by the parameter vector p of states $p_i$ of the combined system and system to genopersistate the system, generates a cost for that system. The cost is the sum of the resources required to genopersistate that system given the particular genopersistation process represented by p.

Examples of parameters within the system which drive cost include energy efficiency, aircraft ceiling, and crew size. Examples of parameters within the system to genopersistate the system which drive cost include the degree to which participative management is used, company standards, requirements definition methodology, the degree and type of automation, the degree to which processes are optimized, the degree and type of employee training, and contractual obligations. Of these, the parameters representing the state of the system to genopersistate the system generally dominate the cost.

The density of all of the possible costs to genopersistate the system may be interpreted as a probability density function [16]. This probability density function can be represented by the high dimensional differential form dC(p) [20]. The integral C(p) defines the distribution function [21] of cost as a function of the joint requirements and specifications of the system and the system to genopersistate the system. C(p) defines the cost risk [5]. A particular cost c is realized on the manifold [3] of parameters p defined by $\{p \mid C(p) = c\}$.

The goal of the design-for-cost process is to attain a parameter p* such that c* is the minimum cost permitted by dC(p). Taguchi methods [22,23] and response surface methodology [18] are both processes which attempt to locate p* if cost is chosen as the quality characteristic. Johnson [13,14,15] demonstrates the design-for-cost process with nonlinear programming [17]. The attainment of p* represents both the minimum cost and the minimum cost risk.

## Cost and the System to Genopersistate the System to Genopersistate the System

It is this system that determines the way the system is genopersistated and hence the cost. What it determines are the requirements and specifications for the system to genopersistate the system. This system determines the components of p which are not determined by customer requirements.

Dean [3] indicates that complexity rather than size is the dominant cost driver. He also indicates that complexity has two components corresponding to the system and the system to genopersistate the system. Thus, this system determines the second component of complexity.

As pointed out by Deming [9], management owns the "system [to genopersistate the system]." Since management controls the system to genopersistate the system, management determines the component of complexity not related to customer desires. Thus, management controls the primary parameters which determine cost. Perhaps there is some truth to the often demonstrated belief by management that the system will cost what they want it to cost! If management really understood the observable and controllable parameters which truly drive cost, then they could truly control the cost. Evidence does not support an hypothesis that management understands the real cost drivers.

## Cost and the System to Genopersistate the System to Genopersistate the System to Genopersistate the System

This system is controlled by the few who have the vision to determine how we need to change the system to genopersistate the system to genopersistate the system to genopersistate the system. The essential function of this system is to genopersistate how to genopersistate projects for quality where cost is defined as a quality characteristic of the system to genopersistate the system.

## Conclusions

Cost is a genopersistational phenomenon not a financial one. If a system is to be allocated a low cost, the system must be genopersistated for low cost. To accomplish this we must first address how to genopersistate the system to genopersistate the system for low cost. This much needed area of research is in an embryonic stage.

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